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Cancer Detection Using NIR Elastic Light Scattering and Tissue Fluorescence Imaging

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Abstract: Near infrared imaging using elastic light scattering and tissue fluorescence under long-wavelength laser excitation are explored for cancer detection. Various types of normal and malignant human tissue samples were utilized in this investigation.

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The feasibility of developing surface or near surface cancer detection methods using near infrared (NIR) light scattering and/or tissue fluorescence is the focus of this investigation. Two main imaging approaches are explored: a) NIR polarized elastic light scattering and b) fluorescence in the NIR spectral region under laser excitation in the green and red spectral regions.

The human tissue samples are studied as they become available after surgery using an imaging system that is located adjacent to the pathology room at the UC Davis Medical Center hospital. A set of images of each tissue sample are recorded. More specifically, the cross-polarized elastic light scattering images under 700-nm, 850-nm and, 1000-nm linearly polarized illumination and the fluorescence images in the 700 to 1000-nm spectral region under 532 and 633-nm laser excitation are recorded. In addition, the two polarization image components of the NIR tissue fluorescence under linearly polarized 632-nm excitation are recorded and used to obtain the degree of polarization and polarization difference emission images. These images are then compared with the pathological assesment of the tissue sample to reveal the optical fingerprint characteristics suitable for cancer detection.

The experimental results indicate that optical detection of cancerous tissue components is possible using the above approaches. The images attained using elestic light scattering delineate differences in absorption and scattering. Such differences were observed in some types of tissue, such as in blader and colon cancer. The NIR emission images obtained under 532-nm laser excitation may arise predominately from flavins, porphyrins, and bilirubins while porphyrins and biliverdins may contribute to the emission under 632 nm laser excitation. NIR fluorescence using 532-nm excitation have shown limited success in highlighting the presence of cancerous lesions. Most succesfull was proven to be the NIR fluorescence imaging approach under 632-nm excitation. The presence of cancer lesions in a field of normal tissue is usually expressed in the NIR emission image as a higher intensity feature. Typical examples are shown in figures 1 and 2.

Figure 1 shows an $\approx 4 \times 3$ cm^2 human breast tissue sample with multifocal high grade ductal carcinoma in situ surrounded by fibrous stroma, adjacent area of fatty infiltration. Fig. 1a shows the cross polarized light scattering image of the sample under 700-nm illumination. Figs. 1b and 1c show the fluorescence images in the 700 to 1000-nm spectral region under 532-nm and 633-nm laser excitation, respectively. Fig. 1d shows the degree of polarization image of the NIR emission under 633-nm excitation. From the images of the sample shown in fig. 1, only the NIR fluorescence image under 633-nm excitation shows a correlation with the histopathological assessment map of the sample. The 1-mm diameter areas of higher emission coincide with the location of the ductal carcinoma lesions in the sample. The emission arising from these cancerous parts of the sample have a higher intensities by a factor of $\approx$2.5 when compared to that of the normal tissue.

Figure 2 shows the cross-polarized light scattering image under 850-nm illumination (a) and the NIR fluorescence image under 632-nm excitation (b) of a tissue sample from human prostate that was surgically removed. A 5×3 mm^2 area of prostatic adenocarcinoma within the peripheral zone is clearly visible in the

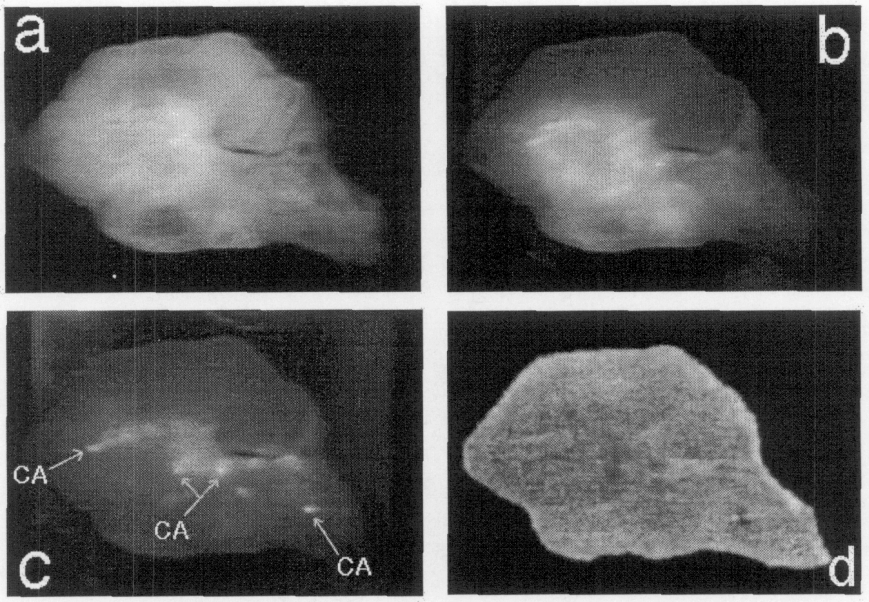

Figure 1. Images of a human breast tissue sample with multifocal high grade ductal carcinoma. A) cross polarized light scattering under 700-nm illumination. Fluorescence images in the 700 to 1000-nm spectral region under B) 532-nm and C) 633-nm laser excitation. D) degree of polarization image of the NIR emission under 633-nm excitation.

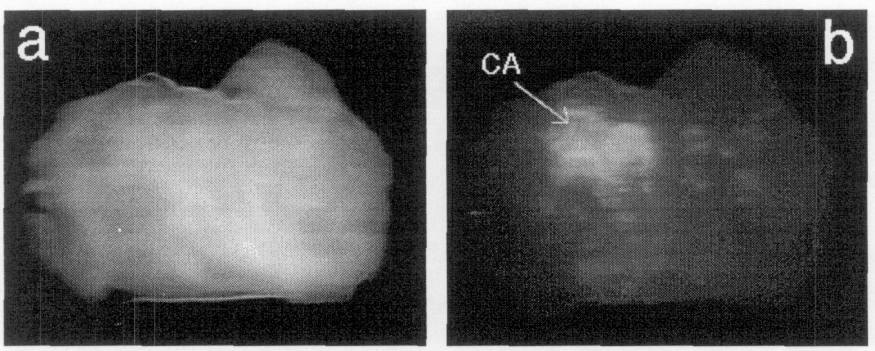

Figure 2: A) Cross-polarized light scattering image under 850-nm linearly polarized illumination and B) NIR fluorescence image under 633-nm excitation of a human prostate tissue sample. The 5 X 3 mm^2 prostatic adenocarcinoma lesion has intensity higher by a factor of ≈3.5 in the NIR fluorescence image.

NIR emission image but not in the light scattering image. It must be noted that the polarization sensitive fluorescence images have shown no dependence of the degree of polarization on the tissue type and in all cases, they were not successful in detecting the presence of cancer. Interimage operations using tissue fluorescence and light scattering images can enhance the visibility of a cancer lesion in some tissue types such as in the uterus.

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